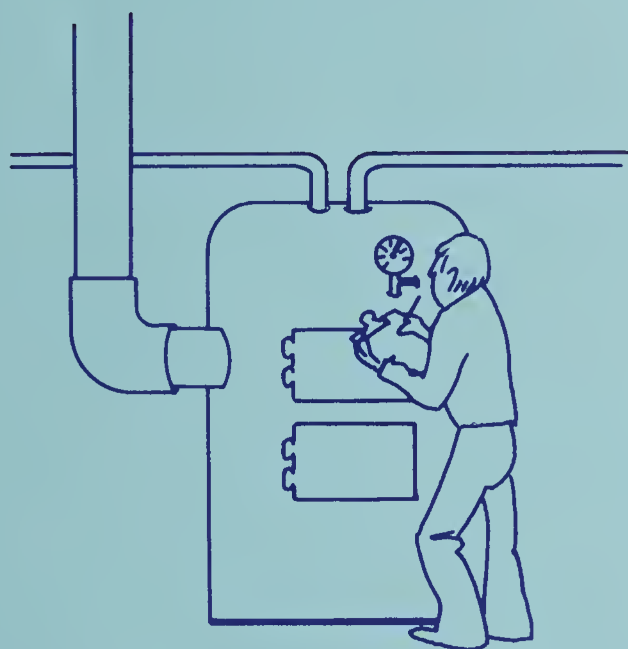
LOCAL GOVERNMENT ENERGY MANAGEMENT SERIES

How to Conserve Energy in Your HEATING, VENTILATING AND AIR CONDITIONING SYSTEMS



Department of Natural Resources and Conservation

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HVAC: THE BIGGEST ENERGY USER

Heating, ventilation, and air conditioning (HVAC) is by far the biggest energy user in any building. So it should be the biggest target for your energy conservation efforts. You probably can save up to 30% of your HVAC energy bill, and if your building has older or improperly operated HVAC equipment, that figure could be even higher.

KNOW YOUR OBJECTIVE: TO FIND THE ENERGY WASTERS IN YOUR HVAC SYSTEM AND TO CORRECT THEM.

Some modifications in your HVAC system will require expert professional advice to implement. Usually, the more complex the HVAC system is the more likely you are to need professional help to modify it. But the results of your walk-through audit may show a surprising number of no-cost and low-cost measures that can be achieved by building staff.

This booklet provides you with a brief overview of heating, ventilation, and air-conditioning systems, and offers some cost effective, no-cost and low-cost O&M measures. In addition, some possible capital measures are presented for you to consider during and after your walk-through audit.

FEEL FREE TO ASK FOR HELP

If you have any questions about the subjects covered in this booklet or if you need help in carrying out any phase of your energy management program, call or write:

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WHAT KIND OF HVAC SYSTEM DO YOU HAVE?

There are many different kinds of HVAC systems. Some buildings have heating systems only, and use windows for ventilation. They may also have separate air conditioning units. Other, usually newer, buildings have complex systems that provide heat, air conditioning, and ventilation all in the same system. These are called "total environmental systems."

There are different energy savings measures for different parts of your HVAC system. There are possible inefficiencies at the primary heating or cooling source (e.g., the boiler or furnace), in the distribution and terminal system (the pipes, radiators, ducts, and vents), and in the HVAC controls your building has.

HEATING SYSTEMS

There are four basic types of heating systems: warm air, hot water, steam, and electrically heated systems.

A warm air system is the simplest of heating systems. Air is heated in a chamber that encloses the combustion chamber and then rises (or is forced by fans) through air ducts to registers in the area to be heated. In a hot water system hot water is circulated by pipes to radiators in the areas to be heated. A control on the boiler maintains a "stand-by" temperature to ensure an adequate supply of hot water. In a steam system, water is heated to create steam, which is circulated through pipes to radiant elements in the areas to be heated. The steam then condenses, and the resulting hot water is piped back to the boiler to be heated again. In electrically heated buildings electricity is converted into heat at the area to be heated, by electrical resistance elements. Some complex "total environment" systems pre-cool air at a central location, and then reheat the same air electrically at the terminal outlet.

Except for electric systems, all of the above systems use the combustion process to heat the air or water. The heat is produced on demand of the thermostats in gas and oil fired systems, and when fueled in solid fuel systems such as coal and wood.

HOW THE COMBUSTION PROCESS WORKS

The burner mixes air with fuel and injects this mixture into the combustion chamber, where it is ignited by a pilot light or by electrodes to produce a flame. This flame first heats air or water that surrounds the combustion chamber by radiation, then the hot gases from the flame pass through a heat exchanger where more heat is absorbed by the heated air or water. The waste gases, containing non-absorbed heat, are exhausted through the stack or flue, while the heated air, water or steam is distributed through the building.

When a burner is firing, a continuous flow of hot gases leaves the combustion chamber and passes up through the heat exchanger section and then up the chimney. The amount of heat carried away by these gases and the amount absorbed by the air or water depends on vaporization of the fuel, the oxygen/fuel mix, the build-up of scale or soot on the heat exchanger surfaces, and the amount of insulation. The amount of heat retained by the system represents the system's efficiency.

Stack losses occur when the heat created by combustion is lost up the stack rather than being absorbed by the air or water being heated. Stack loss accounts for a majority of the heat loss from the heating plant. Stack losses can be increased by dirt on the heat transfer surfaces, by excessive firing rates, by improper vaporization of fuel, and by the furnace being adjusted to take in too much or too little air.

Stand-by losses occur when the burner is not firing, and cold air drawn into the heating plant forces the hot gases up the stack. Radiation losses occurring during periods when the burner is off are also considered stand-by losses.

Radiation and convection losses occur when heat passes through the shell of the boiler or furnace. These losses are due to faulty or insufficient insulation and occur whether or not the burner is firing.

YOU CAN IMPROVE THE EFFICIENCY OF YOUR PRIMARY HEATING SYSTEM

To improve combustion efficiency:

- keep all heat transfer surfaces clean
- fire the burner at the lowest rate possible while meeting the required heat load of the building
- minimize the air taken in without creating excessive smoke that may foul the heat transfer surfaces.

NOTE: The above adjustments must be done by a qualified heating technician to avoid incomplete combustion and the production of carbon monoxide, a poisonous, explosive gas.

To minimize radiation losses:

- repair and add boiler insulation where needed
- operate the system at a lower temperature (or steam pressure) during periods when the full operating temperature (or pressure) isn't needed.

To reduce stand-by losses:

- reduce operating temperatures
- shut down the unit whenever possible
- use automatic flue dampers
- be sure all secondary dampers are shut when the system isn't firing.

NEW TECHNOLOGY IN OIL BURNERS

Many older systems commonly use the rotary cup burner, which is recognized by the horizontal, rapidly rotating cup through which the air and fuel are injected into the combustion chamber. These burners can provide reasonably good efficiency, but it is impossible to maintain this efficiency without almost daily cleaning and service. You should consider replacing your rotary cup burners with the more modern flame retention or air-atomizer burners, suitable to the fuel you now use and the capacity your building needs. Be sure that the new burners are no larger than needed to carry the required load and are equipped with a variable firing rate if possible.

LOSSES IN HEAT DISTRIBUTION SYSTEM

All the heat that is produced in the primary system may not get where it is needed. If your steam or hot water pipes are poorly insulated or not insulated at all, the potential savings from insulating them is substantial and should not be overlooked. Remember that in order to work properly pipe insulation must fit tightly to the pipe, not allowing air to pass between the pipe and the insulation. Potential savings may also be achieved by using valves to close hot water or steam lines that are no longer needed to heat certain areas. Make an effort to shut off any heating lines that are no longer needed.

Underground distribution lines tend to have severe losses because their insulation is seldom if ever inspected. If the insulation becomes wet from ground water, it does not work properly. Also, steam leaks in underground lines may not be noticed unless they are substantial. If several buildings are heated from a central plant, the losses could be considerable.

In steam systems, losses occur when condensate is returned to the boiler in uninsulated lines, when condensate is lost to a drain, and when steam is vented from the system. When condensate is lost from the system, it must be replaced with colder make-up water that must be heated. The quantity of make-up water should be monitored with a water meter to find out how much condensate is lost in the system. Too much make-up water may mean a leak in the system.

STEAM TRAPS—A SPECIAL SOURCE OF HEAT LOSS

Steam traps allow condensate to drain from the steam system while preventing steam from escaping into the condensate line. The steam that escapes into the condensate line is not in itself a system loss, for it only increases the temperature of the condensate. The loss occurs if the heat escapes from the condensate line or if

the condensate does not reach the boiler. If a great amount of steam escapes into the condensate, steam can actually be seen venting from the condensate receiver near the boiler. When the condensate receiver's temperature is high, or steam "plumes" are observed, the steam traps are probably failing.

When looking at each trap, check the by-pass valve as well, which is used when the trap is being serviced. It may leak or be left in the open position. Most steam traps have a test valve; if the discharge contains droplets of water, the trap is working properly. There are other ways to test traps that require special equipment and training. Be sure to obtain the help you may need for this important job.

Sometimes condensate from a high-pressure boiler is returned through low-pressure lines, and re-evaporates into steam. If this steam is vented off it is wasted; it may be possible to pipe it back into a low pressure line.

DON'T FORGET TO LOOK AT THE WATER PUMPS

Water pumps are frequently overlooked, but a small 20 hp pump can cost five thousand dollars per year to operate. Most pumps used in heating systems can be shut off when the outdoor temperature rises above 50°F or 60°F; if automatic thermostatic controls are used for this purpose, savings can be substantial.

You may also be able to reduce the flow rate. If the flow rate is reduced without constricting the system or reducing the pump's efficiency, the power needed for pumping would be reduced by the cube (x^3) of the reduction in the flow rate. Reducing the flow rate can be done by reducing pump speed, by trimming the pump impeller, or by installing a smaller pump.

COOLING SYSTEMS

If your building is cooled by local units (i.e., window or wall air conditioners), the potential for savings lies in monitoring how they are used and in making sure you have efficient equipment of the proper size for the space to be cooled. In central cooling systems there are system efficiencies to be considered.

HOW CENTRAL COOLING SYSTEMS WORK

In a direct expansion system, a refrigerant is passed through a compressor to a condenser where it liquifies and gives off heat. This liquid is then passed through an expansion valve to the evaporator, and as it expands into a gas it absorbs heat from the indoor air. This gas then returns outdoors to the condenser, along with the heat it has absorbed.

In a chilled water system, water passes over the evaporator and is cooled before being distributed to the conditioned area. The heat from the condenser is absorbed by water from a cooling tower. Sometimes direct expansion systems cool condensers with water, too.

A less common system utilizes the absorption cycle, particularly found in facilities where waste steam is available. Steam is used to concentrate a solution of lithium bromide. This concentrated solution absorbs water, causing evaporation and cooling of water in the evaporator. Absorption cooling is the least energy efficient and the most expensive form of cooling. It is justifiable only when its source of heat (the steam) would otherwise be wasted.

VENTILATION AND AIR HANDLING SYSTEMS

You may have a ventilation system as simple as opening and closing windows or as complex as a centralized "total environment" system with variable air volume. All complex systems can waste energy and are good candidates for some simple O&M measures that can save you money. This booklet will help you to implement some of these low-cost and no-cost measures, and will identify some capital measures for your consideration, too.

The air supply in an air handling unit can be any mixture of outside air and indoor air. This mixture of air is controlled by a series of dampers and is regulated by electronic devices. The air then moves through a series of coils that can provide any combination of heating and cooling. If the outside air is excessively cold it is often preheated prior to mixing.

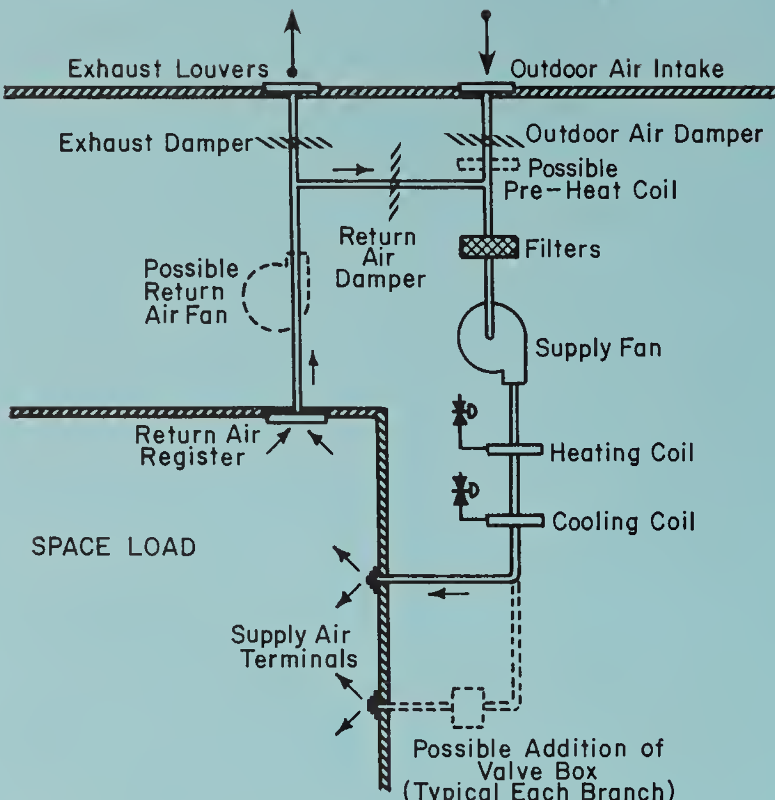
SINGLE ZONE SYSTEMS

The simplest system is the single zone system. Unit ventilators (found in many schools) are single zone air handling units without exhausts.

With proportional control, as the temperature in the space rises, this is what happens when the space is occupied:

1. The heating coil gradually turns off.
2. The dampers gradually take in more outside air if outdoor air is cool enough (in some systems, humidity is also considered to be useful for cooling.)
3. The cooling coil gradually turns off.

When outdoor air either cannot be used for cooling or cooling is not needed, the dampers return to their minimum-outdoor-air-position.



SINGLE ZONE HVAC SYSTEM

TIPS FOR EFFICIENT OPERATION

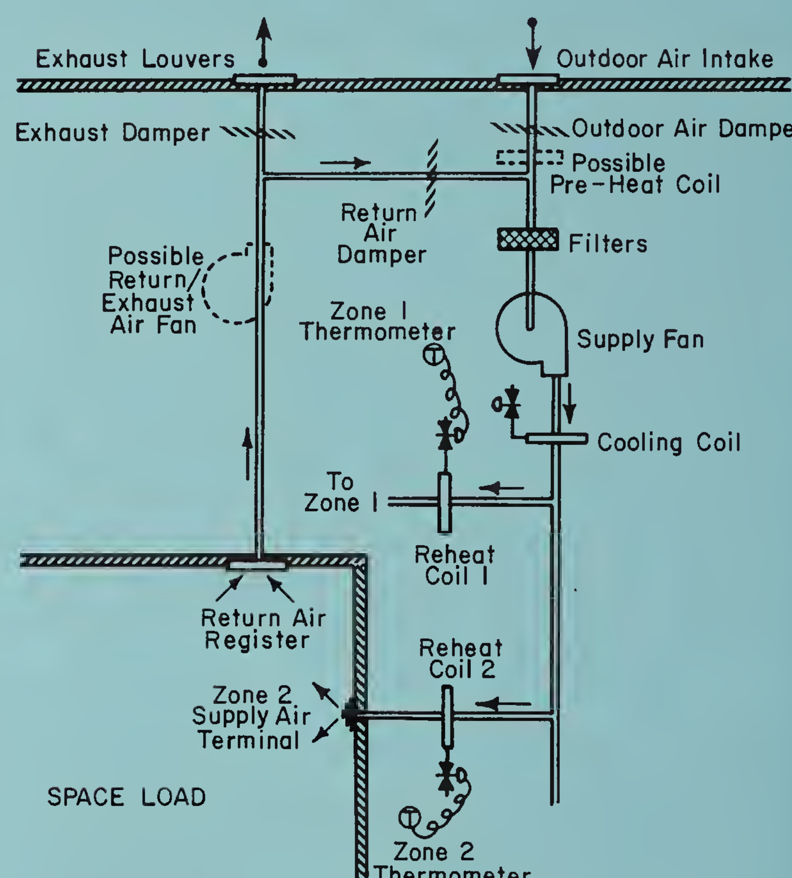
Even if your single zone air handling unit is controlled differently, these tips will help save energy:

- The heating coil should never be on while the outdoor damper is open beyond its minimum position. In fact, there should be a "deadband" between heating and outdoor air intake. That is, the temperature at which the outdoor damper begins to open should be several degrees below the temperature at which the heating coil gradually turns off.
- The outdoor damper should be completely closed during unoccupied periods and especially during morning warmup.
- When cooling is required, the cooling coil should be turned on only when outdoor air cannot handle the load. Even when the cooling coil is on, the outdoor air damper should be open if outdoor air is easier to cool than return air.
- During unoccupied periods, the space temperature should be set back, and the fan should run only when heat is required.

To sum up—the system's various functions should never be allowed to fight one another, and the building should use only as much heat or air conditioning as comfort and code regulations require.

REHEAT SYSTEMS

A reheat system's major advantage is that it can do an excellent job of providing different temperatures in several different zones at the same time. Its major disadvantage is that it is the most wasteful system in common use. Typically in such systems the cooling coil and dampers maintain the air at a constant cool temperature. This temperature is usually 55°F to assure a relative humidity of no greater than 50 percent at 75°F. The 55°F is delivered throughout the building to various zones where it is reheated to meet local requirements. Whenever the building's cooling load is less than maximum, this system is simultaneously heating and cooling the same air.



TERMINAL REHEAT SYSTEM

TIPS FOR EFFICIENT OPERATION

Even a properly operating reheat system is inefficient. However, you can minimize its wastefulness by eliminating the use of the reheat coils as much as possible. Try raising the temperature of the cooled discharge air gradually over the course of several days. This will reduce the load on the reheat coils. You may find that you can get by with a 65°F unit discharge temperature during the winter

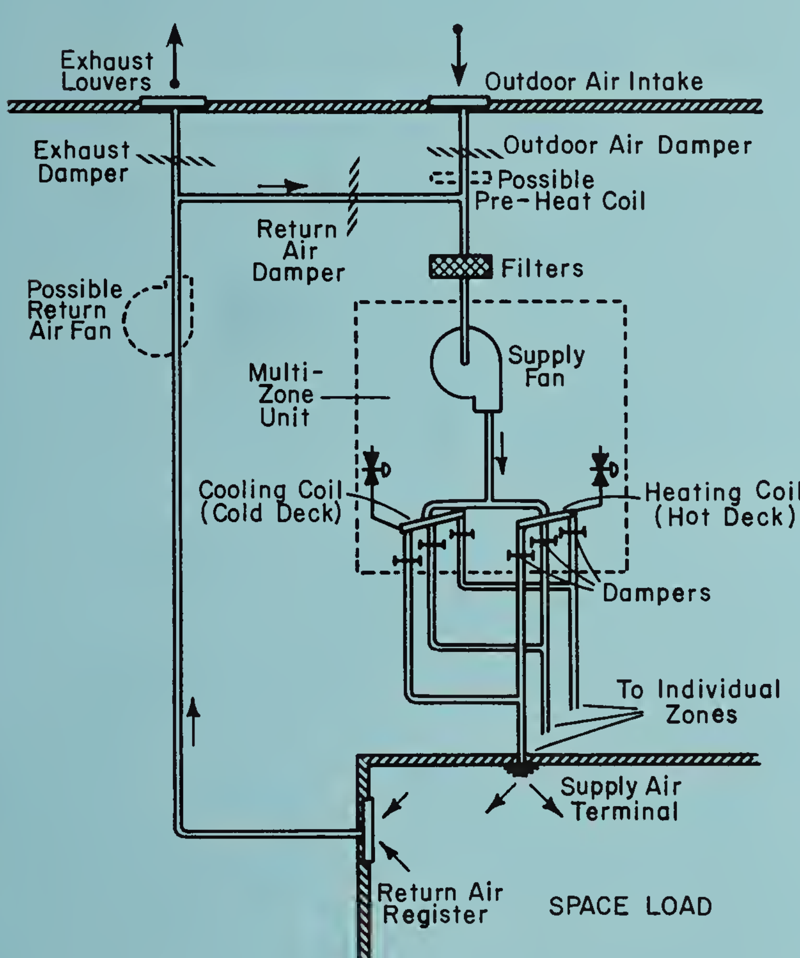
while you might still need 55°F in the summer. Remember, however, that in raising the discharge temperature you are losing control of humidity.

Further improvements are possible, but require modifications in your controls, especially if humidity control is important.

MULTIZONE SYSTEMS

As its name implies, a multizone system can maintain comfort in several zones simultaneously. While it is not as effective as a reheat system in controlling humidity, it also wastes less energy. With minor modifications, a multizone system can be made to operate more efficiently.

The sketch below shows only one zone.



MULTI-ZONE SYSTEM

A typical multizone unit actually has several zones, each with its own thermostat and mixing dampers. If you have a multizone unit that has not been improved in the last ten years, it probably operates in the following manner:

The outdoor, exhaust-air, and return-air dampers are modulated (gradually changed) to maintain a constant mixed air temperature, usually 55°F. The heating coil is regulated to maintain the "hot deck" at a constant temperature, typically around 120-140°F. The cooling coil keeps the "cold deck" at 55°F. Each zone has hot and cold air available to it. The zone thermostats maintain proper space temperature by controlling mixing dampers that mix the heated and cooled air.

TIPS FOR EFFICIENT OPERATION

All improvements to a multizone system should be directed toward minimizing air mixing.

1. The mixed-air temperature should be as high as possible to minimize the load on the heating coil.
2. The hot deck temperature should be as low as possible.
3. The cold deck temperature should be as high as possible.

In most buildings, it is possible to turn off the heating coil during the summer and the cooling coil during the winter. When this is done, the turned-off deck acts simply as a by-pass.

OTHER KINDS OF SYSTEMS

A **dual-duct system** is a multizone system with its hot and cold decks extended by ductworks. Hot air and cold air are distributed separately throughout the building. Mixing takes place in mixing boxes located in or near the areas they serve.

A **variable-volume system** can be very efficient if it is operating properly. Air at a constant temperature is distributed throughout the building. Dampers or air valves controlled by thermostats pass only as much conditioned air as necessary into the areas they serve.

In an **induction system**, a central unit supplies air to terminal units located in conditioned spaces. This air induces an additional flow of room air. The total air flow is heated and/or cooled by coils in the terminal unit. The air from the central unit often is all outside air, which by itself can satisfy ventilation requirements. In many systems, this air is heated in the winter and cooled in the summer. The temperature of this air should be controlled to minimize the amount of reheating or recooling at the terminal units.

NEW TECHNOLOGY IN CONTROLS

With the rise in energy costs, there has been a rapid evolution in HVAC control systems. New control devices have been developed that can reduce or turn off your

HVAC systems when they aren't being used. Some new controls sense outside air temperatures and modify the temperature settings of your primary heating or air cooling systems to suit the weather conditions. Other controls are designed to make energy efficient choices between the temperature and humidity of outside air and inside air, and to select whichever is better suited to the needs of the building and its HVAC system. (See the Capital Investment section of this booklet for more information on HVAC control systems.)

If your building has a "total environment" HVAC system, your controls are crucial to the efficient use of energy. But no matter what kind of HVAC system you have, controls can make major savings in energy use, often without major modifications in your basic HVAC system. These are the basic types of controls on the market today:

In **electric proportional controls**, the controlled device is usually a motor. The motor can drive a valve, a damper, or a series of cam-operated switches. In addition, the motor drives a potentiometer which is balanced against a potentiometer in the thermostat.

More sophisticated control is possible with this system. Controlled devices can be easily operated in sequence. For example, as room temperature rises, the signal from the thermostat can gradually drive the heating water valve to a closed position. When the valve is fully closed, a further increase in temperature can gradually open the outdoor air damper.

Electronic controls are capable of still further sophistication. Their advantages are that their sensors (thermostats, etc) have no moving parts, and they have fewer discrete components to be interconnected. Their major disadvantage is that their operation is hidden in "black boxes."

Pneumatic controls are the most common in large systems. They operate on the same basic principles as the other control systems and are capable of the same control sequences. Control signals are varying air pressures in place of voltages and currents. Thermostats consist of bimetal strips varying the flow of air through orifices. All controlled devices are bellows or pistons operated against adjustable springs.

O&M (OPERATION AND MAINTENANCE) MEASURES

The following OM measures will help you save HVAC energy dollars at little or no cost. In some cases there also are related capital investments that may be cost-effective and therefore worthwhile for you to consider.

#1 on Your List: COMBUSTION EFFICIENCY

CONDUCT BURNER EFFICIENCY TEST AND ADJUST AIR/FUEL RATIO

Application: Applicable to all fuel burning equipment; most critical with oil-fired and non-atmospheric gas-fired equipment.

Description: Inefficient combustion can be a major source of energy waste. Testing your burner and adjusting it to burn fuel more efficiently is one easy and inexpensive way to reduce energy consumption. In many cases a few simple adjustments and an inexpensive part such as a new nozzle can make a major difference. In other instances, the basic design of the burner may be obsolete and it will make good sense to replace the burner with a new and more efficient one. Burners rarely rate higher than 82-84% on efficiency tests, and any reading in the low-to-mid seventies indicates substantial room for improvement.

TELLTALE SIGNS

The following conditions indicate improper burner maintenance or adjustments:

- Impingement of the flame upon combustion chamber walls, causing quenching of the flame (and the generation of smoke in oil fired equipment). In oil fired equipment, flame impingement is often revealed by a blackening of a portion of the cumbustion chamber wall.
- (In oil fired equipment) the presence of sparks in the flame. The sparks are droplets of oil that the burner has failed to atomize properly.
- A lop-sided, uneven flame. This condition indicates non-uniform distribution of fuel or air.
- An excessively reddish or yellowish flame.
- Excess air (indicated by low CO_2 or high O_2). This is a direct indication of inefficient combustion. If air is not leaking into the combustion chamber from cracks in the boiler itself, the presence of too much excess air indicates improper burner adjustment. The air damper on the burner may have been opened to compensate for smoky combustion due to some defect that must be remedied before the air quantity can be reduced.

SERVICE

All burners should be serviced at least once a year. Monthly service is desirable; rotary cup burners must be serviced monthly. This servicing must be done by skilled

and experienced burner mechanics. If in-house personnel are not highly skilled at burner servicing, it is poor economy to have them do the work and then pay the fuel costs resulting from efficiency even one or two percent lower than it could be. Whoever is responsible for your burner should perform the following functions:

- Perform or monitor regularly scheduled combustion tests and maintain a log of the results.
- Determine whether the equipment is being improperly serviced and whether efficient combustion is being maintained.
- Observe and report any degradation in the performance of the equipment.
- If necessary, make adjustments in the air-to-fuel ratio.

THE COMBUSTION EFFICIENCY TEST

It is strongly recommended that all operators of fuel burning equipment learn how to test for burner efficiency and regularly perform these tests. The literature accompanying the testing equipment provides detailed information on how to conduct the various tests and on the significance of the tests. The following notes are intended to give a brief overview and to point out some common errors in performing the tests.

Instruments Used: You may use either a single testing device that has a probe and meters to provide readings, or a set of instruments consisting of the following:

- A stack thermometer
- A CO_2 indicator (or an O_2 indicator)
- A smoke tester
- A draft gauge

The single testing device performs the same tests as the set of instruments (except it measures O_2 rather than CO_2). The cost of a set of instruments is in the $150-$200 range, the electronic device around $500-$600.

In the instrument set, the stack thermometer is designed to be inserted in the flue to determine the temperature of the effluent gases.

The CO_2 indicator is a container with a graduated scale, partially filled with a special liquid that absorbs the CO_2 contained in a flue gas sample. As a result of changes in volume in the liquid, the CO_2 contents of the flue gas can be read directly on the scale.

The smoke tester is a small hand-operated vacuum pump. A filter paper is inserted, and a gas sample is drawn through the paper. Soot particles discolor the paper, and the intensity of the resultant "smoke spot" is then compared to a chart with spots that are graduated on a scale of intensity from 0 to 10.

Finally, the draft gauge is used in order to measure whether the stack, the barometric damper setting and possibly an induced draft fan provided for the air pressure conditions are needed to overcome the resistance to air flow offered by the equipment when it is firing.

SOME TIPS CONCERNING TESTING AND ADJUSTING BURNERS

Measuring the Stack Temperature (exit gas temperature): the stack temperature should be measured with a thermometer that reaches at least halfway through the flue as close as possible to the breach and before the barometric damper (if any). It should also be as close as possible to the center of the flue, as there is often severe stratification of temperatures within flue passages. The thermometer must remain in place long enough for its needle to stop moving. If a service technician does not wait for this to happen, the equipment being tested will appear more efficient than it actually is.

CO_2 Test: The CO_2 test is used to determine the amount of air that is being taken in for each unit of fuel that is burned. The CO_2 sample should be taken from the location in the stack at which the temperature is measured.

O_2 Test: The O_2 test may be performed instead of the CO_2 test. Its advantage is that a reading of zero O_2 corresponds to no excess air, while the amount of CO_2 corresponding to no excess air varies somewhat with the composition of the fuel. The O_2 test consequently provides more accurate results, particularly in equipment that operates with very little excess air.

Draft Measurements: Draft is the negative pressure that is developed within the boiler and the stack. Since draft requirements vary widely from one burner to another, the significance of draft measurements can only be interpreted by people familiar with the requirements of the equipment being tested. In general, however, the following considerations apply:

- Draft affects the rate at which air is drawn in by the burner, so a change in draft due to a change in outdoor temperature may affect the air/fuel ratio.
- Draft determines the rate at which air is drawn into the combustion chamber through cracks and dampers. Consequently, it is desirable that the draft be kept as low as possible consistent with the requirements of the burner.

Draft should be measured over the fire and in the flue where other combustion tests are taken in accordance with the instructions provided with the test equipment. Excessive cracks should be repaired.

Smoke Test: Smoke density is normally tested by drawing a specific volume of combustion products through a specific area of filter paper and comparing the darkness of the resulting spot with shades provided in a comparison chart. Oil burners firing No. 2 oil should be

adjusted to the minimum air setting that provides no more than a No. 2 smoke spot on the smoke scale.

ESTIMATING YOUR SAVINGS

The savings that can be obtained by improving combustion efficiency may be calculated easily and with reasonable accuracy by means of the following formula:

A. Actual, current efficiency of the burner (as determined by the combustion efficiency test)
= % A

B. Assumed, future improved efficiency of the burner (your efficiency target)
= % B

To calculate DOLLAR SAVINGS:

$$\$/yr \times \frac{(1 - \%A)}{\%B} = \$/yr\ C$$

$/yr = Total annual cost from fuel bills

O&M
CLEAN BOILER TUBES AND HEAT TRANSFER SURFACES

Application: Applies to all oil fired boilers and furnaces. A regular cleaning program should be in effect.

Description: Heat transfer surfaces should be brushed and vacuumed or blown down frequently to keep them clean. If soot is as much as 1/32 inch thick, cleaning is overdue. Look at your heat transfer surfaces and check the thickness of the deposit. If your unit is equipped with soot blowers, these should be used in accordance with the manufacturer's recommendations.

Example of Savings: A 1/32 inch layer of soot will increase fuel consumption by about 2% over what it would be with clean heat transfer surfaces. Under the present maintenance program, if the thickness of soot averages 1/32 inch and the annual fuel cost is $50,000, an annual savings of $1,000 could be expected to result from thorough and frequent cleaning of the heat transfer surfaces.

O&M
HVAC 1 LOWER INDOOR TEMPERATURES DURING THE HEATING SEASON TO 65°F

O&M
HVAC 2 RAISE INDOOR TEMPERATURES DURING THE COOLING SEASON TO 78°F

Application: You will want to consider these fundamental ways to achieve substantial savings. When lowering temperatures consider the age of building occupants, remembering that accidental hypothermia (a drop in deep body temperature) can be fatal for infants and elderly.

Description: You may have only one thermostat to adjust, or several throughout your building. On some HVAC systems you can make appropriate adjustments on the controlling thermostat for every zone in your building. It may be best to make gradual adjustments to allow occupants to become more accustomed to the changes.

For terminal reheat systems, keep the use of the reheat coils down to a minimum, if they can't be turned off completely. With reheat systems, even in the cooling mode, raising temperatures causes more energy to be used. On many multizone units, the heating coil operates all year. The hot deck can be turned off and act simply as a by-pass. A good capital investment to investigate would be to modify the system to eliminate the use of reheat coils.

Example of Savings: Up to 12-14% can be saved annually on fuel consumption in a building that operates 40 hours a week year round with winter thermostat settings of 65° (instead of 72°) and summer settings of 78° (instead of 72°).

O&M
HVAC 3 REDUCE OUTSIDE INTAKE TO MINIMUM REQUIRED LEVELS

Application: Outside air is needed to remove odors and to provide adequate "fresh" air for occupants. A certain amount of outside air enters every building, perhaps mainly through a mechanical ventilation system, but also accidentally through infiltration leaks around doors and windows, through leaky vents, and through open windows. Because of all these extra sources of outside air, most ventilation systems take in more outside air than is needed. Along with reducing infiltration in the building envelope, you will also want to reduce the amount of air admitted by your ventilation—in most instances, 5 cfm per person. This O&M measure may yield substantial savings in most buildings with either central or unitary HVAC systems. For more information on reducing infiltration, please refer to another publication in this series, "How To Conserve Energy in Your Building Envelope."

Description: Many ventilation control systems have a minimum outside air adjustment. This adjustment prevents the controls from calling for less than a predetermined amount of outside air. This setting should be as low as code allows.

In most systems, outside air intake is not constant. It usually varies in accordance with the demands of a room thermostat or a mixed-air-temperature controller. Minimizing outside air intake requires modification of the sequence of control (discussed below).

In some simple systems, outside air intake is a constant percentage of total air supply. In these systems, reducing outside air intake is simply a matter of adjusting damper linkages.

In systems that take in 100 percent outside air, reducing air intake is best accomplished by reducing fan speeds: this will save fan energy as well. Any reduction in the amount of outside air intake should be coordinated with exhaust. If outside air is reduced, and the exhaust fans continue to try to remove the original amount of air, infiltration through doors and windows could cancel much of the savings. Also, in hospitals, the resulting imbalance could be in violation of code.

Laboratory exhaust hoods are major users of outside air. They should be run only when necessary and at the lowest safe speed. In many cases it may be cost-effective to provide hoods with their own supply of slightly tempered outside air, rather than allowing them to exhaust valuable room air.

Fans should be turned off during unoccupied periods whenever possible. If the fan system is used for heat during unoccupied periods, it should be run only on a demand for heat, and the outside air dampers should remain closed. The dampers should also remain closed during morning warmup after night setback.

Example of Savings: In a building that uses a total of 40,750 cfm of 100% outside air, approximately $25,000 can be saved by reducing the outside air intake by about 30%, to 28,000 cfm. This $35,000 savings amounts to 30% of the original $80,000 annual cost.

O&M
HVAC 4 ELIMINATE UNNECESSARY USE OF HVAC SYSTEM AT NIGHT AND DURING UNOCCUPIED HOURS

Application: This measure applies to virtually all buildings that are unoccupied at night or for a day or more. In some buildings only a portion of the building is used at night; if the unused areas have their own thermostatic controls, some savings will be possible. Checking the occupancy pattern of your building and the locations, types, and settings of thermostats and other controls will tell you what kind of set-back you should consider.

Description: Night set-back of the heating system requires that either an assigned person or an automatic timing device (e.g., a clock thermostat) turn down the thermostat setting every afternoon to 55 degrees and turn it back up early in the morning. The actual time of day for changing the setting may vary and will depend upon the season and the severity of the weather on particular days. The responsible person should proceed on a trial and error basis to determine how long it takes for the building to heat up in the morning and to cool off in the afternoon.

Once a "feel" for these time lags is established, the operator should aim to have the building reach 65 degrees about 30 minutes after the occupants arrive and should probably set back the temperature 30 to 60 minutes before the building closes. An optimal start/stop control uses a microprocessor to monitor the weather and building performance and automatically decides optimal start/stop times. Occupants coming out of the cold weather will find the relative warmth retained in the building comfortable. If the building or a separately zoned area (see HVAC 5) is unoccupied for a day or more (e.g., over a weekend), the heating system should be turned down to 55°.

Air handling and cooling systems should be completely shut down if all or part of the building is unoccupied at night and during any other unoccupied periods, except in areas where health codes require adequate ventilation around the clock.

In newer buildings, time clocks are often provided that can automatically control the night set-back and perhaps weekend set-backs as well. The operators only have to choose the proper settings for set-back to occur. If you don't have clock thermostats, time clocks, or a zoned system, the investment may be justified by potential savings.

Example of Savings: Turning back the thermostats from 65° to 55°F during unoccupied times can save up to 15 percent of your total fuel costs.

O&M
HVAC 5 SHUT DOWN HVAC SYSTEMS IN UNOCCUPIED AREAS

Application: Applies to all multizone systems, particularly in those buildings that may be fully occupied during the day but in which some areas are not used during the evenings.

Description: This is similar to night set-back. The heat in unoccupied areas should be reduced to 55°, and air handling and cooling should be completely shut down. If there is a regular pattern of use or occupancy, time clocks can be used to shut down the systems. It may be possible to consolidate evening activities into fewer zones, allowing systems in more areas to be set back.

O&M
HVAC 6 LOWER HOT WATER TEMPERATURE (OR STEAM PRESSURE) LEAVING BOILER

O&M
HVAC 7 LOWER HOT WATER SUPPLY TEMPERATURES FOR HEATING COILS AND ROOM RADIATION

Application: These measures apply to steam or hot water boilers and distribution systems. Steam pressures and hot water temperature should be kept as low as possible to minimize distribution losses.

Description: Temperatures can be adjusted at the aquastat located on the boiler; if there is a mixing valve located past the boiler, adjustments can be made there as well. The closer to the boiler the adjustments can be made, the more distribution losses will be reduced. Ideally, the temperature should be just high enough to heat the building on the coldest day of the year. But even with this "ideal" setting, the water will be too hot during the rest of the heating season. Experimenting will allow you to determine just how much you can reduce the supply temperature or steam pressure without losing heating capability during the coldest weather. Also consider making adjustments at various times during the season.

O&M
HVAC 8 ADJUST TEMPERATURE OF AIR DISCHARGED FROM AIR HANDLING UNITS

Application: Applies to all air handling units, and especially in terminal re-heat systems. Quite often the settings on the hot decks and cold decks can be adjusted or even disconnected during the appropriate season.

Description: In many systems the hot deck is set at 120°F and the cold deck is set at 55°F. In a reheat system the discharge air is reheated in the various areas by the local heating coil. Raising the discharge air temperature, usually a simple adjustment at the main control panel, reduces the load on the cooling system and on the reheat coils.

Note that controls occasionally are not marked, so before making adjustments be sure you know what you are adjusting. In fact, with rebalancing the system (done with the assistance of a professional technician) you may be able to eliminate reheat coils entirely. If you find that you must use reheat coils to maintain comfort levels even after rebalancing, you may want to consider installing variable volume dampers in spaces subject to overcooling.

Estimating Your Savings: Especially in a large building, savings can be substantial. However, adjusting air discharge temperatures is not similar to the simple reduction of the settings on room thermostats, and the savings are difficult to estimate. Although savings can't easily be predicted, remember that this is a no-cost measure and that the payback will be immediate, no matter what savings are achieved. The greatest savings will result if the hot and cold decks are disconnected entirely during the appropriate season.

O&M
HVAC 9 RAISE TEMPERATURE OF CHILLED WATER SUPPLY

Application: If your central air conditioning system uses chilled water, the chilled water supply temperature may be set lower than is necessary to do the job. Raising the temperature of the chilled water supply will reduce the heat gained by the water supply as it cools the building.

Description: Making the temperature adjustment may require assistance from the equipment manufacturer or a qualified professional, but you can determine whether it is a good idea. Read the temperature from the insertion thermometer on the supply piping that leads from the chiller into the building system. If the reading is lower than 48°F (it is often as low as 40-42°F), the temperature can probably be raised. A reasonable range for the setting would be between 48 and 52°F. Also, note whether the insertion thermometer is in good condition; if the mercury is separated, a new thermometer is needed.

Example of Savings: Savings cannot be calculated accurately, but as a rule of thumb you could estimate that you would save 1% on your cooling costs for every degree the supply temperature is increased. So, with cooling costs of $20,000 a year, a 4° increase might save $800 a year.

O&M
HVAC 10 CLEAN REFRIGERATION CONDENSER TUBES AND COILS REGULARLY

Application: This measure applies to the tubes in all condensers and to all cooling throughout the air handling system.

Description: The condenser tubes should be inspected annually to determine whether any build-up of scale has occurred. One way to determine the need for cleaning is to inspect the water in the cooling tower of your building. If the water is rust-colored or contains scales, cleaning is necessary. Coils will require more attention and should

be inspected more frequently. Cleaning simply requires a brushing down and vacuuming of the coils to remove any buildup that will decrease the efficiency of the coils.

O&M
HVAC 11 REPLACE AIR FILTERS REGULARLY

Application: Applies to all HVAC systems (except hot water or steam systems in buildings where there is no air conditioning and no mechanical ventilating system). The filters collect dust and dirt from incoming outside air and from return air. Not only does this prevent the conditioned air from becoming unpleasant, it also protects the fans, motors and other devices from becoming inefficient due to dirt and dust particles and it will prolong the useful life of your equipment.

Description: The most common filter type is a dry filter of porous material from one to two inches thick. Quite often such filters are disposable, although some can be cleaned with water. Filters are located after all intake ducts, and before the heating and cooling coils of the system. Part of your maintenance schedule should include inspecting and either replacing or cleaning filters once a month.

O&M
HVAC 12 BE SURE HVAC CONTROLS WORK PROPERLY

Application: This measure applies to all HVAC systems. Controls are the most important components in an HVAC system. Their proper adjustment and maintenance are critical to minimizing energy usage. It is important to realize that many types of control failure have no effect on comfort but have a significant effect on energy consumption.

Description: A minimal control maintenance program should include the following:

1. Keep thermostats and temperature sensors in proper calibration.
2. Check time clocks for proper settings and placement of on/off tabs (especially after a power failure).
3. Make sure valves, dampers, linkages, and motors operate freely.
4. In pneumatic systems, periodically check control-air filters, oil separators, and dryers.

If a control component fails, repair or replace it; do not bypass or disable it "temporarily." Temporary repairs have a way of becoming permanent. Whenever control technicians are in your building, watch them carefully. Learn as much as you can; controls are not as complicated as they look.

O&M
HVAC 13 REDUCE FAN SPEEDS AND ADJUST BELT DRIVES

Application: Applies to all fans and motors in air handling systems. Most fans are oversized. In order to leave some margin for error, designers generally allow for slightly higher air qualities than are actually needed. If an air handling system can always handle its heating or cooling load, there is a good chance that the fan speed can be reduced.

However, even though fan or motor speeds may be reduced, they should not be reduced too much. In slowing fans, you should be aware of the following:

1. A drastic reduction in speed can cause instability. Check with the fan manufacturer.
2. In a DX (direct expansion) cooling system, reduced air flow can decrease the refrigeration efficiency. This loss in efficiency should be weighed against fan energy savings.
3. Whenever air flow rates are changed, improper air balance can result.

Description: Many people respond to this problem by cycling fans; that is, they install timers to turn fans off for a short time periodically; say ten minutes out of every hour. This method of reducing fan capacity has the advantage of flexibility: use of the timer can easily be discontinued during periods of heavy load. However, it does not save nearly as much energy as reducing fan speed and therefore should be used in conjunction with speed reduction wherever possible.

Slowing a fan down can be accomplished by installing a larger sheave (pulley) on the fan and/or a smaller sheave on the motor. Many fans have adjustable sheaves that make speed adjustment relatively simple. If you have a fan with adjustable sheaves, the best approach is trial-and-error. Reduce the fan speed until you find the lowest acceptable speed. If slowing down a fan requires the purchase of new sheaves, you may want to do a load analysis first, or you could try cycling the fan to determine whether it is oversized. If you find that you can leave the fan off for 15 minutes out of every hour, then you could slow the fan by 25%. Make sure that belts are tight so there is no slippage, just as you would do on the fan or alternator belts on your car.

Often, more air is needed for cooling than for heating. If an air-handling system supplies both, installation of a two-speed motor might be economically justifiable. In some cases, installation of an additional motor on the same drive belt could be considered. This motor would have a smaller pulley and would be smaller in horsepower than the existing motor.

Example of Savings: About $15 a year could be saved if just one fan with a 2 hp motor, that operates 40 hours each week year round, can be reduced to 90% of its current speed, (assuming electricity costs 4.5 cents/kWh).

O&M
HVAC 14 MAINTAIN STEAM TRAPS

Application: Applicable to all two-pipe steam systems.

Description: Steam traps are found in all two-pipe systems; their job is to allow only hot water from the condensing steam to return to the condensate receiver, while preventing steam from returning as well. If a trap malfunctions, steam can return to the condensate or even escape down the drain instead of heating the building. A good way to determine if traps are not working is to monitor the temperature of the condensate receiver; a sudden rise may indicate that a trap has failed. Also watch for steam plumes from the receiver, and try to determine their cause. All steam traps and by-pass valves should be checked on a regular basis—annually if you have a low pressure system, and monthly if you have a high pressure system. When a trap is found to be defective, have it repaired or even rebuilt according to the manufacturer's recommendations.

Savings: If a defective trap allows steam to return to the condensate receiver, a portion of the steam's heating value simply will be retained within the heating system and eventually will be piped back into the building. But this portion will be small if the condensate line is uninsulated, allowing for heat loss through the pipes. If the condensed steam lines empty into a drain, the heat will be lost altogether. The key is to keep the steam heat where it will be of the most use: In the occupied areas of the building.

Example of Savings: In a building with a low pressure system, a steam trap that had failed completely could waste energy at the rate of almost $400 a year (assuming natural gas costs $5.00/mcf and boiler efficiency is 75 per cent).

O&M
HVAC 15 REPAIR DISTRIBUTION PIPE INSULATION

Application: Applies to all steam, hot water and chilled water distribution systems.

Description: Inspect all systems annually for defective or missing insulation. The insulation should fit snugly around the pipes and there should be no cracks and no gaps between sections. Steam traps should not be insulated, nor should a 2-foot section of condensate line downstream of each trap.

Insulation thickness somewhat greater than those used in the past usually is cost-effective, but it is not normally cost-effective to add insulation to lines that are already properly insulated.

Attention to details is important in repairing or replacing pipe insulation, since even a small section of uninsulated line can dissipate (or absorb, in the case of a chilled water line) a substantial amount of heat.

Some of the distribution system may be closed off with valves rather than insulated. This may be a cost-effective capital investment for you to make. Survey your system to determine whether or not each section of hot pipe is actually needed as part of the system and whether there are any sections of pipe that can be valved off temporarily or permanently. In particular, consider valving off underground lines when they are not needed.

Example of Savings: Insulating 100 feet of uninsulated 1½-inch pipe might save somewhere in the range of $170 each year if the hot water temperature is 180°F.

O&M
HVAC 16 REPAIR EXISTING LOCKING THERMOSTATS AND LOCK UNGUARDED THERMOSTATS

Application: Applies to all thermostats whose settings can easily be tampered with. In some of the newer thermostat control systems, sensors are located in various parts of the building but the temperature settings are controlled by a console at a remote location (such as an office or mechanical room that can easily be locked). Most thermostats, however, are the familiar type that combine the sensor and the control in one unit located in a heavily used area.

Description: Maintaining the proper thermostat setting is crucial to the success of your energy conservation program. To prevent tampering with settings, all thermostats should be locked. Repair the locks you now have, close up holes that could be used to change settings, and consider the relatively small investment of buying locking enclosures for presently unguarded themostats.

Savings: No further savings should be added to those you already estimated for O&M HVAC 1 and 2 (lowering heating and raising cooling temperature settings). Actually, you should consider this as just a minor additional cost for ensuring that those savings are realized.

OTHER O&M MEASURES TO CONSIDER

These are some O&M measures that may yield savings in your HVAC system:

- Seal cracks and openings in the walls of the boiler or furnace, to prevent air leakage into the combustion chamber.
- Reduce the firing rate of the burner to the minimum possible while still maintaining the required heating load for the building.
- Repair the insulation surrounding the boiler on furnace, using a high temperature insulating cement and chicken wire for reinforcement.
- Monitor the boiler make-up rate with a water meter, to determine the amount of condensate that is lost in the system.
- Shut off circulating pumps when not needed, reduce the flow rate within the pumps, or consider installing smaller pumps (this may be considered a capital item in some buildings).
- Use shades, blinds, or draperies to admit or block the heat of the sun and to reduce heat loss (or gain) at night; this will reduce the building's heating and cooling loads.
- Exterior shading devices, where feasible, are much more effective than blinds or draperies.
- Rewire restroom exhaust fans to operate only when the lights are on. Consider a timed switch.
- Examine ductwork to detect possible obstructions (e.g., loose hanging insulation in lined ducts), loose turning vanes and accessories, or closed dampers.

CAPITAL INVESTMENT

While many savings opportunities are no-cost or low-cost, many more opportunities will require capital investment. Here are some capital improvements to consider for your HVAC system. You will need the expertise of a qualified professional to evaluate and implement the measure that will be the most cost-effective for you.

FUEL BURNING EQUIPMENT

- Add a control to the boiler to provide automatic shut-off when heat is not needed.
- Replace an inefficient burner (such as a rotary cup burner or an old coal burner that has been converted to gas) with a modern, efficient burner of a type suitable to the fuel being used. The capacity of the new burner should be no larger than necessary to carry the present and anticipated load. If possible, a burner with a variable firing rate should be installed.
- Insulate hot, uninsulated boiler surface, with tight fitting, removable glass fiber blankets especially fabricated for this purpose.
- Install an automatic flue damper to close the flue when the unit is firing.
- Consider installing turbulators in fire tube boilers to increase turbulence within the boiler passages and thereby improve heat transfer and reduce stack temperature.
- Replace standing gas pilots with electrical or mechanical ignition systems.
- Consider replacing your existing boiler with a new boiler of the most efficient design available, if your present boiler is grossly oversized; if it lacks sufficient heat transfer surface to maintain an acceptable low stack temperature when carrying full load; or if it is otherwise inefficient and cannot be brought up to good efficiency in a cost-effective manner by replacing the burner, rebuilding the combustion chamber, sealing air leaks, installing turbulators, or other measures.
- In large boilers consider installing automatic combustion control systems, which monitor the composition of the exit gases and fine-tune the amount of air taken in.

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